# VERITAS: VERY ENERGETIC RADIATION IMAGING TELESCOPE ARRAY SYSTEM

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### **ABSTRACT**

A next generation atmospheric Cherenkov observatory is described based on the Whipple Observatory  $\gamma$ -ray telescope. A total of nine such imaging telescopes will be deployed in an array that will permit the maximum versatility and give high sensitivity in the 50 GeV - 50 TeV band (with maximum sensitivity from 100 GeV to 10 TeV).

## INTRODUCTION

Recent successful detections in Very High Energy (VHE)  $\gamma$ -ray astronomy using the atmospheric Cherenkov technique have triggered a spate of projects aimed at extending and improving the detection technique. Although these projects (at various stages of conceptual design, detailed planning or actual construction) have radically different experimental approaches, they have important features in common: (i) all are based on the belief that the scientific benefits gained by an increase in sensitivity justify a major effort; (ii) all are agreed that major improvements in sensitivity are physically possible and technically straightforward; and (iii) by the standards normally used in this field all the projects are expensive (in the \$3M to \$15M range).

State-of-the-art imaging Atmospheric Cherenkov Telescopes (ACTs) are best represented by: the Whipple Collaboration telescope in southern Arizona [Reynolds et al. 1993], the French CAT telescope in the French Pyrenees [Punch 1995], the Armenian-German-Spanish HEGRA telescope array in the Canary Islands [Petry et al. 1995], the Durham telescope in Narrabri, Australia [Chadwick et al. 1995], the Australian-Japanese telescopes at Woomera, Australia [Tanimori et al. 1995], the Russian SHALON- ALATOO project at Tien-Shan [Sinitsyna 1995], the Crimean Astrophysical

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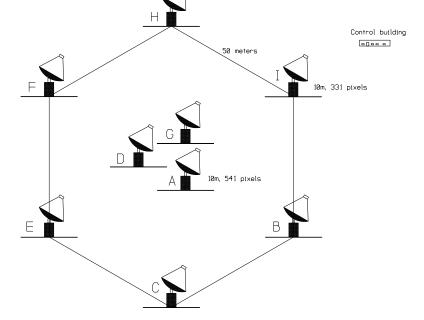


Fig. 1: Layout of telescopes in VERITAS.

Observatory telescopes [Zyskin et al. 1995], the Indian TACTIC Array at Mount Abu, India [Bhat et al. 1993] and the Japanese Telescope Array in Utah, USA [Hayashida et al. 1996].

The Whipple Observatory  $\gamma$ -ray telescope consists of a 10m diameter optical reflector focussed onto an array of PMTs. The energy threshold is  $\sim 300$  GeV and the telescope routinely obtains a  $5\sigma$  excess from the Crab Nebula in one-half hour of on-source observations. In 1996 the 109 pixel camera was expanded to 151 pixels and eventually it will have 541 pixels [Lamb et al. 1995]. Although the 10m reflector was built in 1968 and the first imaging camera installed in 1983, this is still the prototype device for atmospheric Cherenkov imaging systems.

The features of VHE ACTs that can be improved include: (a) energy threshold; (b) flux sensitivity; (c) energy resolution; (d) angular resolution; (e) field of view. Of these, energy threshold is the easiest to achieve since energy threshold scales as (mirror area)<sup>-1</sup>. The proposed detector, VERITAS, would make improvements in all these parameters.

#### **VERITAS**

The philosophy underlying VERITAS comes from 30 years of development of ACTs at the Whipple Observatory [Weekes 1996]; the objective is to build a VHE  $\gamma$ -ray observatory which will have a useful lifetime well into the next century. The initial aim is to have the maximum sensitivity in the 100GeV-10TeV range but to have significant sensitivity down to 50 GeV (and lower as new technology photo-detectors become available) and as high as 50TeV (using the low elevation technique [Krennrich et al. 1997]). The detection technique will be the so-called "imaging" atmospheric Cherenkov technique which was originally demonstrated at the Whipple Observatory but is now under considerable development at a number of centers. The strawman design for VERITAS will have the basic telescopes modelled on the Whipple 10m telescopes with wide field cameras of 331 to 541 pixels. The array will consist of nine such telescopes, all capable of independent or coincident operation. The telescope layout will be as shown in Figure 1. A somewhat similar array (HESS) has been proposed by the Heidelberg group (F.Aharonian, private communication); it would have 16 telescopes with wider separations than envisaged here and would probably be located in Spain.

The preferred location of VERITAS is a flat area at the Whipple Observatory Basecamp (elevation 1.3km) where there is ample space for development as well as easy access to roads, power, etc. An alternative site, with somewhat less area, is also under consideration; this is at the 2.15km level of

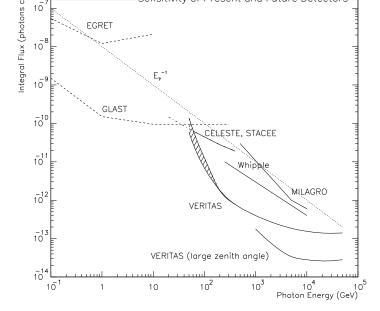


Fig. 2: Predicted sensitivity of VERITAS. Also shown are the known sensitivities of EGRET and Whipple and the predicted sensitivities of the MILAGRO, STACEE, CELESTE and GLAST experiments, all of which are at various stages of planning and construction. The exposure for VERITAS, STACEE and CELESTE is 50 hours. The exposure for EGRET, GLAST and MILAGRO is one year of sky survey operation.

Mt. Hopkins, just below the present site of the Whipple telescope. Southern Arizona has been shown to be an excellent site for these kinds of astronomical investigation with an impressive record of clear nights. These dark sites is not environmentally sensitive nor is there the potential for conflict with other astronomical activities.

The parameters of the array are chosen to give the optimum flux sensitivity in the 100GeV-10TeV range which has proven to be rich in scientific returns. The predicted flux sensitivity is shown in Figure 2; it is seen to be a factor of ten better than any other detector in this range. In these two decades of energy the major background comes from hadron-initiated air showers for which successful identification methods have been developed. At the lower end single muons become the major background but these can be removed by the coincident requirement in the separated telescopes Also at lower energies, the cosmic electron background constitutes an irreducible isotropic background. Over these two decades of energy the angular and energy resolutions will be pushed to their limits (0.05° and 8% respectively).

#### **CONCLUSIONS**

There are a number of alternative projects designed to increase the sensitivity of telescopes in the 10GeV-10TeV range. These include the solar farm projects (STACEE in the USA [Ong et al. 1995] and CELESTE in France [Quebert et al. 1995]), the single dish approach (MAGIC in Germany [Mirzoyan 1997]), the large water Cherenkov air shower detector (MILAGRO in New Mexico, USA [Yodh 1996]), the next generation space telescope (GLAST which will not be launched before 2004 [Gehrels et al. 1997]). All of these have merit in particular areas; the relative merits of these projects are compared with VERITAS for different experimental parameters in Table 1. In this table the ranking system is \*\*\* = excellent; \*\* = very good: \* = good and blank = not good. Timiliness is defined as how quickly will the project come to fruition and cost is in inverse proportion to the total expenditure. Although the \*'s are toted, a better representation might be \* per dollar. Since both the choice of parameters and the ranking are assigned by the lead author it is not surprising that VERITAS

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Table 1: Comparison of Proposed Projects

Concept	Solar Farm	Single Dish	Array	Particle	Space
Project	STACEE	MAGIC	VERITAS	MILAGRO	GLAST
Energy Threshold	***	**	*	*	***
Dynamic Range	*	**	**	**	***
Flux Sensitivity	*	**	***	*	***
Energy Resolution	*	*	***	*	**
Angular Resolution	*	**	***	*	**
Field of View		**	***	***	***
Cost	***	**	**	**	
Timeliness	***	**	**	***	*
TOTAL (*)	13	15	19	14	17

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## **REFERENCES**

Bhat, C.L. et al., Proc. of Workshop on Major Atmospheric Cherenkov Detectors-II, Calgary, Canada, Ed. R.C.Lamb, Publ. Iowa State Univ., 101 (1993).

Chadwick, P.M. et al., Workshop on Gamma-Ray Astrophysics, Padua, Ed. M.Cresti, 301 (1995).

Gehrels, N. et al., Proc. 4th Compton Symposium, Willamsburg, Virginia (in press) (1997).

Hayashida, N. et al., Proc. Int. Symposium on Extremely High Energy Cosmic Rays, Tanashi, Japan Ed. M.Nagano, 205 (1996).

Krennrich, F. et al., ApJ, 481, 758 (1997).

Lamb, R.C. et al., Proc. ICRC (Rome), 2, 491 (1995).

Mirzoyan, R., Proc. Int. Symposium on Extremely High Energy Cosmic Rays, Tanashi, Japan Ed. M.Nagano, 329 (1996).

Ong, R.A. et al., Proc. Workshop on Gamma-Ray Astrophysics, Padua, Ed. M.Cresti, 241 (1995).

Petry, D. et al., Proc. Workshop on Gamma-Ray Astrophysics, Padua, Ed. M.Cresti, 141 (1995).

Punch, M., Proc. Workshop on Gamma-Ray Astrophysics, Padua, Ed. M.Cresti, 356 (1995).

Quebert, J. et al., Proc. Workshop on Gamma-Ray Astrophysics, Padua, Ed. M.Cresti, 248 (1995). Reynolds, P.T. et al., ApJ. 404, 206 (1993).

Sinitsyna, V.G., Proc. Workshop on Gamma-Ray Astrophysics, Padua, Ed. M.Cresti, 133 (1995).

Tanimori, T. et al., Proc. Workshop on Gamma-Ray Astrophysics, Padua, Ed. M.Cresti, 316 (1995). Weekes, T.C., Space Sci. Rev. 75, 1 (1996).

Yodh, G.B., Proc. Int. Symposium on Extremely High Energy Cosmic Rays, Tanashi, Japan Ed. M.Nagano, 341 (1996).

Zyskin, Yu.L. et al., J.Phys. G. 20, 1851 (1994).